

Changes in Mottled Sculpin and Johnny Darter Trawl Catches after
the Appearance of Round Gobies in the Indiana Waters of Lake
Michigan

THOMAS E. LAUER, PAUL J. ALLEN, AND THOMAS S. MCCOMISH

Aquatic Biology and Fisheries Center

Department of Biology

Ball State University

Muncie, IN 47306

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Abstract.---We investigated the response of the mottled sculpin *Cottus bairdi* and the johnny darter *Etheostoma nigrum* to the invasion and proliferation of the round goby *Neogobius melanostomus* at three near-shore locations in southern Lake Michigan. Fish were collected by trawling from June through August, 1984 to 2002. Mean annual catches of mottled sculpins in trawl samples ranged from 0 to 4.4/h from 1984 to 1998, while mean annual johnny darter catches ranged from 0 to 29/h in the same period. Round gobies were first sampled in 1998, with relative population abundance building in the following years, ranging up to 371/h at site K by 2001. From 1999 to 2002, only a single mottled sculpin and only 12 johnny darters were collected in 72 hrs of trawling. This study documents the rapid decline of the mottled sculpin and johnny darter following the round goby invasion to this portion of the lake.

The round goby *Neogobius melanostomus* was first observed in southern Lake Michigan in Calumet Harbor IL in 1993; round gobies then spread east to Hammond Harbor in 1994, East Chicago and Burns Harbor in 1995, and near Michigan City in 1998 (Charlebois et al. 1997; Camp et al. 1999). Establishment of the round goby in this portion of the lake, as well as the rest of the Laurentian Great Lakes (Crossman et al. 1992; Jude et al. 1992) and its subsequent impacts on native fishes and ecosystem function is causing concern to resource managers (Charlebois et al. 2001).

Although impacts of the recent invasion of the round goby have not been fully determined, it has been suggested that increases in population density most heavily influence other benthic fish species such as sculpins *Cottus* spp., darters *Etheostoma* spp. and logperch *Percina caproides* (Jude et al. 1992). The round goby has been successful in out-competing mottled sculpins *Cottus bairdi* and logperch, and preying upon lake trout eggs (Chotkowski and Marsden 1999; French and Jude 2001; Janssen and Jude 2001), and may be influencing community structure. This hypothesis has been supported by both laboratory and experimental field data, particularly on the recruitment failure of mottled sculpins in Calumet Harbor (Janssen and Jude 2001). However, this phenomenon has not been broadly observed in Lake Michigan. Moreover, no studies have delineated demographic

trends in native benthic fish populations comparing pre- and post- invasion periods in the near-shore or open waters of Lake Michigan. Therefore, the objective of this study was to determine the response of mottled sculpin and johnny darter *E. nigrum* populations to the round goby invasion in southern Lake Michigan. In addition, this study chronicles the timing of round goby invasion and population expansion to this region of Lake Michigan.

Study Area

Three sample stations were located in the southern basin of Lake Michigan at the 5 m depth contour (Figure 1). Station K (center of station: N 41.42.26, W 86.56.48) was approximately 2.8 km southwest (227° compass bearing) from the Michigan City IN harbor entrance. Station M (center of station: N 41.37.45, W 86.53.12) was approximately 1 km east of Washington Park Michigan City (compass bearing of 68°), and station G (center of station: N 41.44.27, W 87.15.07) was located approximately 5.7 km from the Burns Ditch harbor entrance (compass bearing of 259°) near the city of Gary. The bottom substrate from Michigan City west to Gary is generally composed of flat sandy areas. However, station K additionally has intermittent clay depressions of up to 1 m or more in depth, creating an irregular bottom structure that is quite different from the surrounding

flat, sandy areas known from this portion of the lake (McComish et al. 2000). Visual observations during scuba dives on the sampling zone confirmed the heterogeneous bottom. All areas were generally free of large rocks, boulders, debris, and allochthonous material.

Methods

Fish were collected with a semi-balloon bottom trawl from June-August between sunset and 2400 hours once in each of six time periods: June 1-15, June 16-30, July 1-15, July 16-31, August 1-15, and August 16-31. Collections were made annually from 1984 through 2002 for stations M and K and from 1989 through 2002 for station G. Each sample consisted of six trawl tows of 10 minutes in length, giving a total sample effort of one hour. All captured fish were separated by tow, and placed in bags on ice in portable coolers and sorted dockside the next day. More detail on the site location and trawling methods can be found in Shroyer and McComish (1998).

Individual trawl tows on a particular night were not statistically independent of each other and were combined into a single value. Thus, six samples (one per time period) each were obtained at stations M and K annually for 19 years, while six samples were collected yearly at station G for 14 years, giving a total sample size of $N = 312$. A failure to meet normality

assumptions precluded the use of several statistical tests to determine changes in the mottled sculpin and johnny darter populations after the goby invasion. This resulted principally from the large number of zero values found in the data set for all three species. A Kruskal Wallis test was used to evaluate differences in johnny darter, mottled sculpin, and round goby catch among stations M, K, and G for the years 1989-1998 and 1999-2002. Additionally, a Chi-square test for association was used to determine changes in the mottled sculpin and johnny darter frequency of occurrence between the pre-(1984 to 1998) and post-(1999 to 2002) goby invasion periods. This analysis was based on presence/absence of mottled sculpins and johnny darters in a particular sample, rather than actual trawl catch. All statistical tests are described by Zar (1999), with $\alpha = 0.05$.

Results

Johnny darters were captured in just over half of all samples (165/312) and annual mean catches ranged up to 29.50/h (Table 1). Differences in annual mean catch among stations M, K, and G were not significant within the sample periods 1989-1998 and 1999-2002 (Table 2). The frequency of occurrence of johnny darters from 1984 to 1998 for all stations combined was 64% ($N = 240$), while this frequency dropped to 15% ($N = 72$) in the 1999 to 2002 period (Table 3). Individual stations M, K, and G each

followed a similar trend (Table 3), although station G showed a more rapid decline (Table 1).

Mottled sculpins were most frequently captured and with the highest catch rate at station K from 1984 through 2002 in the southern basin of Lake Michigan (Table 1). Catch at this station in some years was restricted to one or only a few fish while no fish were captured in 1985, 1986, 1988, and the three most recent sampling years 2000, 2001, and 2002. The mean annual number of fish caught during 1989-1998 at stations G and M were significantly lower than K (Table 2), only ranging up to 0.50/h during the period of record (Table 1). Station K also showed a significant higher frequency of occurrence (37%) when compared to stations M (9%) and G (2%) ($X^2 = 33.3$, $P < 0.01$, Table 1). Frequency of occurrence values changed at station K after the appearance of the round goby, declining significantly to 4% for the period 1999 to 2002 (Table 3). The frequency of occurrence dropped to zero for 1999-2002 for both stations M and G (Table 3). However, no statistical differences could be determined as chi-square computation assumptions could not be met (see Zarr 1999).

Round goby were first collected in 1998 at stations M and G, where they were found in low relative abundance and low frequency (Table 1). The following four years showed an expanding population, increasing in both catch rate and

frequency of occurrence. However, station K had the highest mean annual catch of round gobies, ranging up to 371.3/h (Tables 1, 2).

Discussion

Reduction of the mottled sculpin and johnny darter catches to near zero in 2000, 2001, and 2002 concomitant with the round goby expansion cannot be viewed as coincidental. Although these populations between 1984 and 1999 were present in low amounts (Table 1), they were consistent in occurrence until the round goby invasion.

Round gobies have been suggested to negatively influence the mottled sculpin, among other benthic fish species, when they co-exist (Jude et al. 1995; Jude and DeBoe 1996; Janssen and Jude 2001). Jude et al. (1995) proposed three hypotheses leading to the demise of the mottled sculpin by the round goby: out-competing them for food, for shelter, and for spawning sites. The latter hypothesis was supported by Janssen and Jude (2001), in which round gobies interfered with mottled sculpin nesting sites, thereby causing recruitment failure. In addition, Dubs and Corkum (1996) suggested the aggressive behavioral interactions of the round goby toward the mottled sculpin would likely result in its demise in the wild. It seems likely these same negative influences are affecting the johnny darter in a similar manner in southern Lake Michigan.

The index trawl sampling of this study not only allowed documentation of the time of round goby invasion in the extreme southern basin, but it also provided a quantitative measure of the decline in mottled sculpin and johnny darter spanning the 19-yr period of sample records. Other capture methodologies could be used for this assessment, such as small-mesh traps, and diver or angler surveys, but may be logistically more difficult in the southern basin of Lake Michigan. In contrast, the use of 51 mm stretch mesh gill nets are more easily deployed, but capture only the largest gobies in the near-shore fish community (McComish et al. 2000). Thus, qualitative observations of establishment and quantitative densities in Lake Michigan have been difficult to document.

The larger catch of round gobies at station K suggests this station has environmental features that are different than stations M and G. Shroyer and McComish (1998) described station K as having a heterogeneous bottom with deep (1 m or more) clay depressions and is in contrast to the flat sand bottom at stations M and G. This variation in habitat along the 5 m trawl depth may provide an explanation for the differences in trawl catch observed among stations K, M, and G.

A more rapid decline of johnny darter frequency of occurrence was indicated at station G, with parallel declines at stations M and K lagging behind a year. This could have easily

been due to a differing rate in invasion by the round goby, or other environmental differences among these stations. The round goby in southern Lake Michigan likely originated from a Calumet City IL invasion (Charlebois et al. 1997) and moved east, explaining this temporal inconsistency.

The population depression of the mottled sculpin and johnny darter in the extreme southern near-shore waters of Lake Michigan is almost certainly occurring because of biological interaction with the round goby. This follows a pattern that has been observed with other exotic species in the Great Lakes, such as: sea lamprey *Petromyzon marinus* impacts on lake trout *Salvelinus namaycush*; alewife *Alosa pseudoharengus* impacts on lake whitefish *Coregonus clupeaformis* bloater *Coregonus hoyi*; and yellow perch *Perca flavescens*; and white perch *Morone americana* and Eurasian ruffe *Gymnocephalus cernuus* impacts on a variety of native species (Lawrie 1970; Mills et al. 1993; Mills et al. 1994; Shroyer and McComish 2000; Madenjian et al. 2002). Although the extent of the round goby's impact on native fishes is still developing, it is likely understated and may not be fully understood for some time.

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References

- Camp, J. W., L. M. Blaney, and D. K. Barnes. 1999. Helminths of the round goby, *Neogobius melanostomus* (Perciformes: Gobiidae), from southern Lake Michigan, Indiana. Journal of the Helminthological Society of Washington 66:70-72.
- Charlebois, P. M., L. D. Corkum, D. J. Jude, and C. Knight. 2001. The round goby (*Neogobius melanostomus*) invasion: Current research and future needs. Journal of Great Lakes Research 27:263-266.
- Charlebois, P. M., J. E. Marsden, R. G. Goettel, R. K. Wolfe, D. J. Jude, and S. Rudnicka. 1997. The round goby, *Neogobius melanostomus* (Pallas), a review of European and North American literature. Illinois-Indiana Sea Grant Program and Illinois Natural History Survey. INHS Special Publication No. 20.
- Chotkowski, M. A., and E. J. Marsden. 1999. Round goby and mottled sculpin predation on lake trout eggs and fry: field predictions from laboratory experiments. Journal of Great Lakes Research 25:26-35.

- Crossman, E. J., E. Holm, R. Cholmondeley, and K. Tuininga. 1992. First record for Canada of the rudd, *Scardinius erythrophthalmus*, and the round goby, *Neogobius melanostomus*. Canadian Field-Naturalist 106:206-209.
- Dubs, D. O. L., and L. D. Corkum. 1996. Behavioral interactions between round gobies (*Neogobius melanostomus*) and mottled sculpins (*Cottus bairdi*). Journal of Great Lakes Research 22:838-845.
- French III, J. R. P., and D. J. Jude. 2001. Diets and diet overlap of nonindigenous gobies and small benthic native fishes co-inhabiting the St. Clair River, Michigan. Journal of Great Lakes Research 27:300-311.
- Janssen, J., and D. J. Jude. 2001. Recruitment failure of mottled sculpin *Cottus bairdi* in Calumet Harbor, southern Lake Michigan, induced by the newly introduced round goby *Neogobius melanostomus*. Journal of Great Lakes Research 27:319-328.
- Jude, D. J., and S. F. DeBoe. 1996. Possible impact of gobies and other introduced species on habitat restoration efforts. Canadian Journal of Fisheries and Aquatic Sciences 53:136-141.
- Jude, D. J., J. Janssen, and G. Crawford. 1995. Ecology, distribution, and impact of the newly introduced round and tubenose gobies on the biota of the St. Clair and Detroit

- rivers. Pages 447-460 in M. Munawar, T. Edsall and J. Leach, editors. The Lake Huron ecosystem: ecology, fisheries and management. Amsterdam: SPB Academic Publishing.
- Jude, D. J., R. H. Reider, and G. R. Smith. 1992. Establishment of Gobiidae in the Great Lakes basin. Canadian Journal of Fisheries and Aquatic Sciences 49:416-421.
- Lawrie, A. H. 1970. The sea lamprey in the Great Lakes. Transactions of the American Fisheries Society 99:766-775.
- Madenjian, C. P., G. L. Fahnenstiel, T. H. Johengen, T. F. Nalepa, H. A. Vanderploeg, G. W. Fleischer, P. J. Schneeberger, D. M. Benjamin, E. B. Smith, J. R. Bence, E. S. Rutherford, D. S. Lavis, D. M. Robertson, D. J. Jude, and M. P. Evener. 2002. Dynamics of the Lake Michigan food web, 1970-2000. Canadian Journal of Fisheries and Aquatic Science 59:736-753.
- McComish, T. S., S. M. Shroyer, and T. E. Lauer. 2000. Population characteristics and models of the yellow perch in Indiana waters of Lake Michigan and the community dynamics of major near-shore fish species. Final Project Report for 1996-2000. Federal Aid Project F-18-R, Study 6, Year 4. Indiana Department of Natural Resources. Indianapolis IN.

Mills, E. L., J. H. Leach, J. T. Carlton, and C. L. Secor. 1993.

Exotic species in the Great Lakes: a history of biotic crisis and anthropogenic introductions. *Journal of Great Lakes Research* 19:1-54.

Mills, E. L., Leach, J. H., Carlton, J. T., and Secor, C. L.

1994. Exotic species and the integrity of the Great Lakes. *Bioscience* 44:666-676.

Shroyer, S. M., and T. S. McComish. 1998. Forecasting abundance

of quality-size yellow perch in Indiana waters of Lake Michigan. *North American Journal of Fisheries Management* 18:19-24.

Shroyer, S. M., and T. S. McComish. 2000. Relationship between alewife abundance and yellow perch recruitment in southern Lake Michigan. *North American Journal of Fisheries Management* 20:220-225.

Zar, J. H. 1999. *Biostatistical analysis*. Prentice Hall. Upper Saddle River, New Jersey.

TABLE 2. Kruskal Wallis test results describing variation in johnny darter, mottled sculpin, and round gobies trawl catch among stations M, K, and G in the Indiana waters of Lake Michigan from 1989 to 1998 and 1999 to 2002. Values used for each year are annual means from 6 sampling dates/yr and can be found in Table 1.

	Sample N/Site			Degrees of freedom	<i>P</i>
	M	K	G		
Johnny darter					
1989-1998	10	10	10	2	0.46
1999-2002	4	4	4	2	0.35
Mottled sculpin					
1989-1998	10	10	10	2	<0.01
1999-2002	4	4	4	2	0.37
Round goby					
1989-1998	NA	NA	NA	NA	NA
1999-2002	4	4	4	2	0.01

TABLE 3. Comparison of mottled sculpin and johnny darter frequency of occurrence for pre (1984-1998) and post (1999-2002) round goby invasion periods in the extreme southern basin of Lake Michigan. Values designated as * indicate test assumptions could not be met and the Chi-square test was not calculated.

	Number of sample periods	Johnnie darter			Mottled sculpin		
		Freq. of occur. N (%)	χ^2	<i>P</i>	Freq. of occur. N (%)	χ^2	<i>P</i>
Station M							
1984-1998	90	46 (51)	3.1	0.079	10 (11)	*	*
1999-2002	24	5 (21)			0 (0)		
Station K							
1984-1998	90	63 (70)	6.0	0.015	41 (46)	7.9	<0.01
1999-2002	24	5 (21)			1 (4)		
Station G							
1989-1998	60	45 (75)	13.3	<0.01	2 (3)	*	*
1999-2002	24	1 (4)			0 (0)		
All stations combined							
Pre 1998	240	154 (64)	20.2	<0.01	53 (22)	13. 0	<0.01
1999-2002	72	11 (15)			1 (1)		

FIGURE 1. Location of the three trawl sites: M, K, and G, in the southern basin of Lake Michigan. All sites were located along the 5 m depth contour and were approximately 0.75 km in length.